Procedural Modeling of Cities

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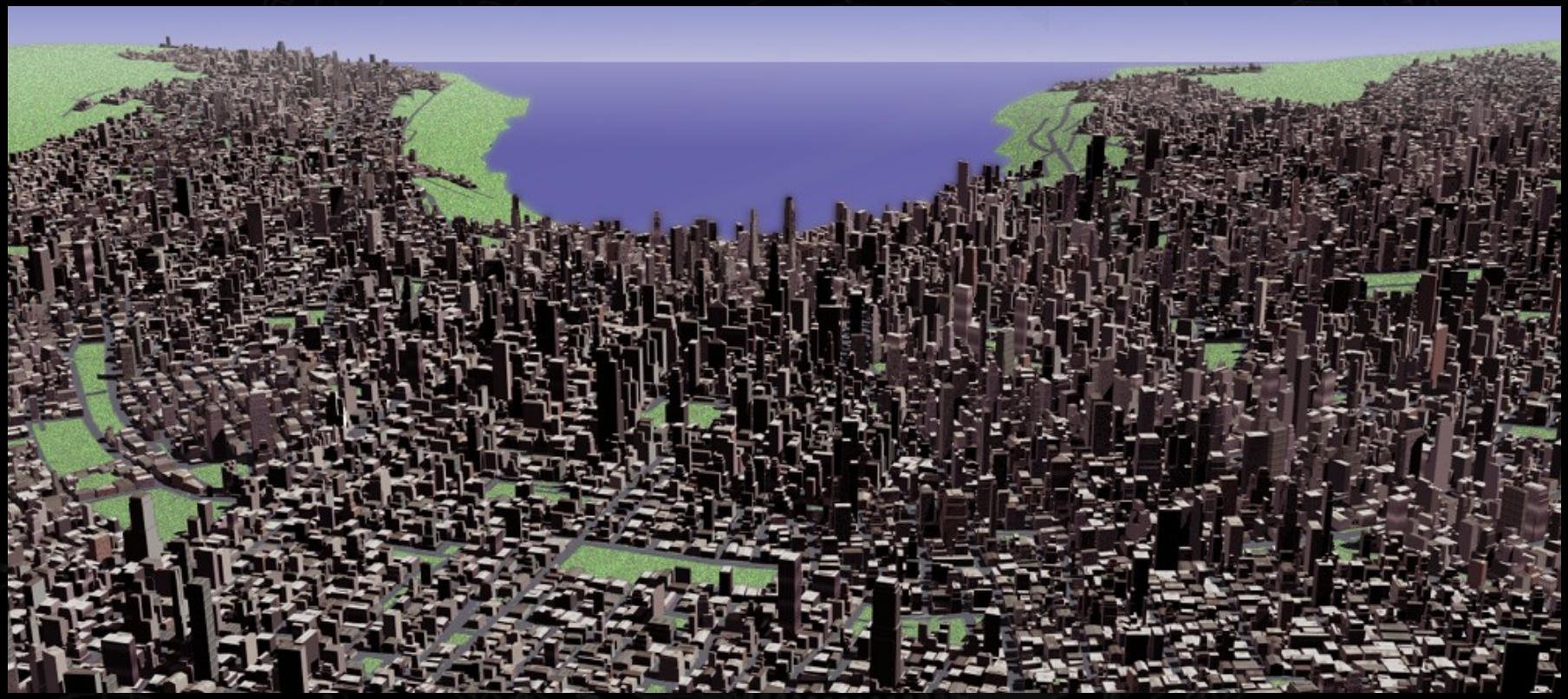
The City Engine System

Procedurally creates complex city models.

Cities consist of:

- **Street maps**
- **Buildings**
- **Facade textures**

Example Zurich-London-Paris



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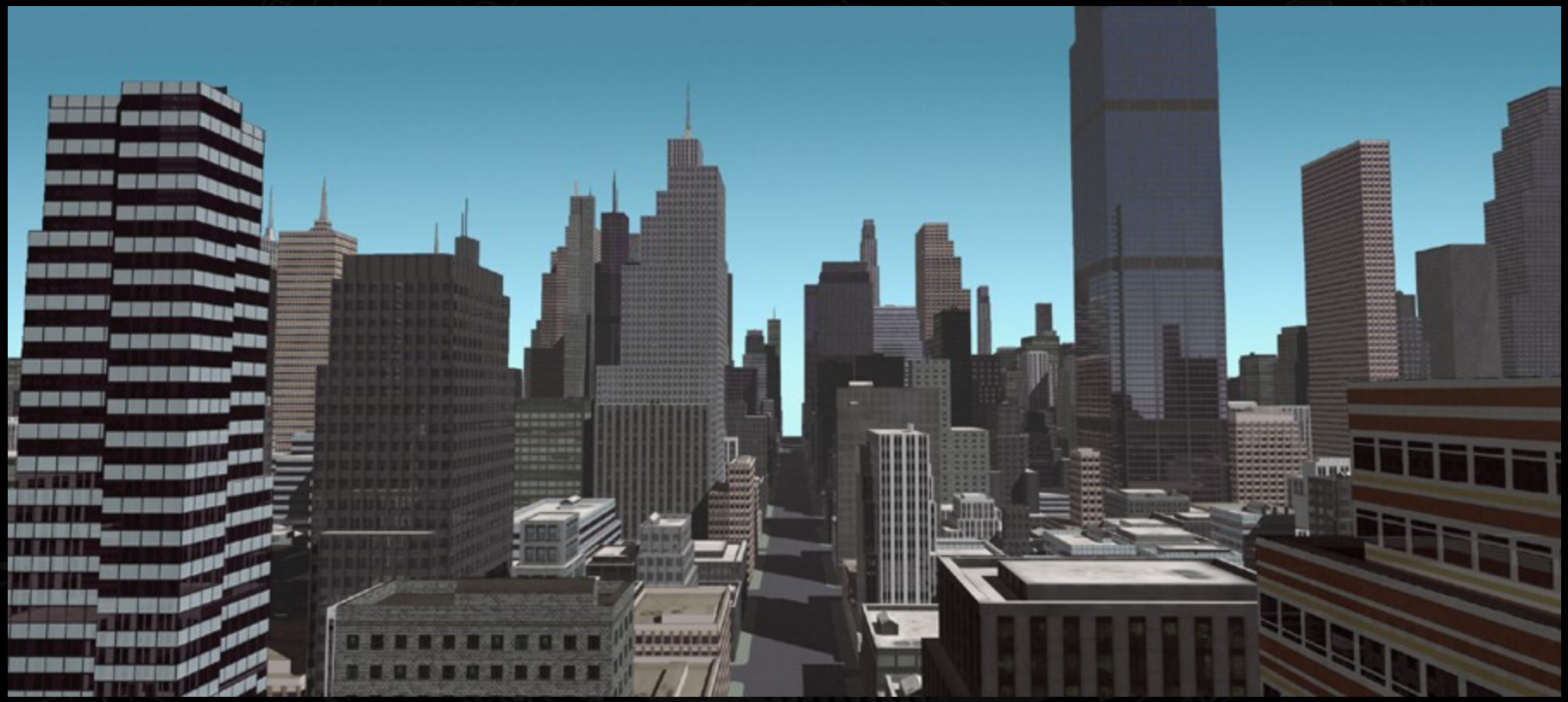
Example Manhattan



Example Manhattan 2259

Overview

1. **Introduction**
   Motivation and system pipeline
2. **L-Systems**
   From streets to buildings
3. **Textures and results**
   Rendering of the results

Motivation

- Many applications in entertainment, simulation and visualization
- Cities as virtual „backdrops“ are hard to model by hand
- Procedural methods have been used to model complex environments

Related Work

- **Mostly satellite-imagery based systems**

  e.g. Henricsson, Streilein, Gruen; 1996

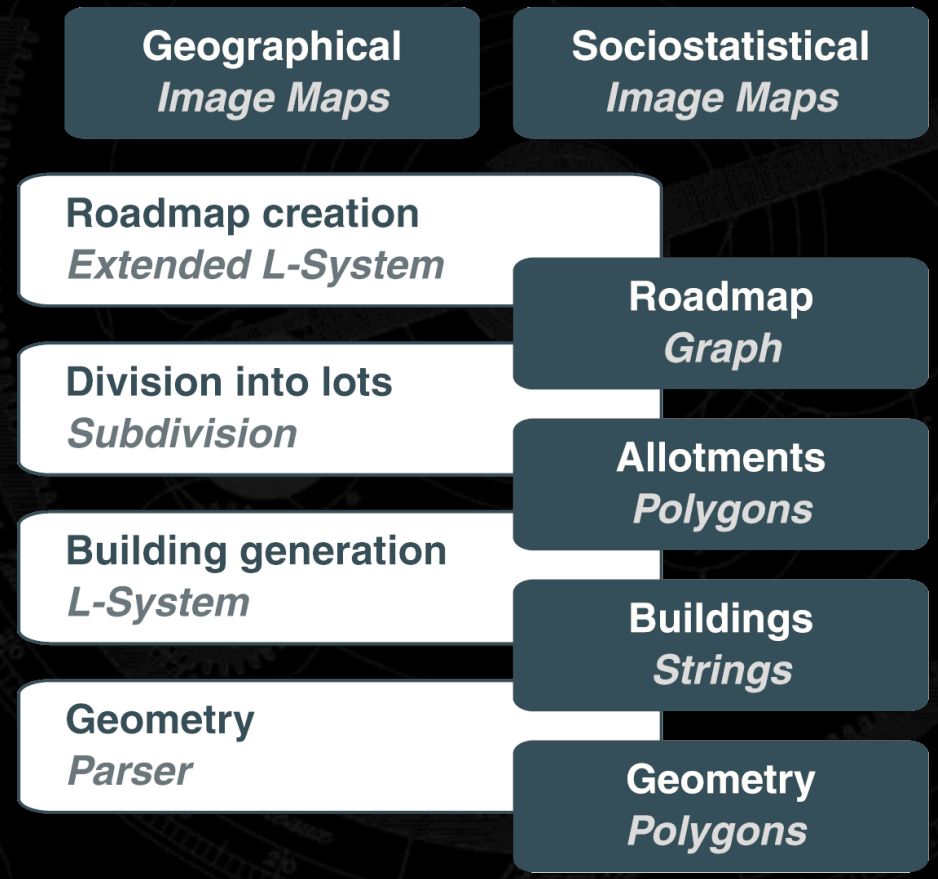
- **Work on visualization of large data sets**

  e.g. Davis, et al.; 1999

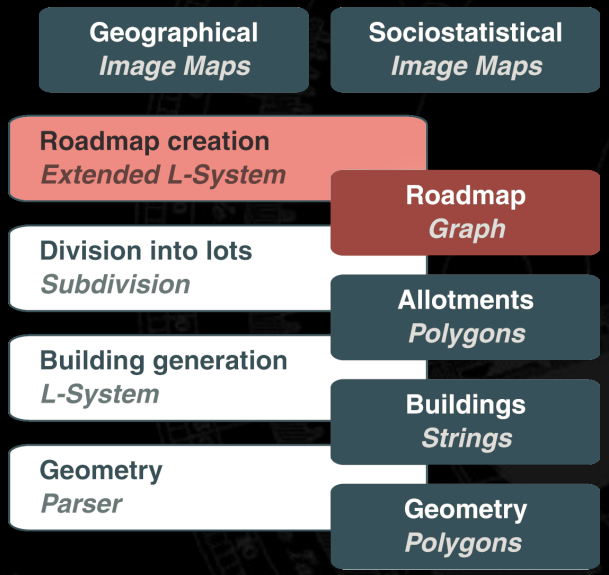
- **Similar projects are still in the making**

  Yap; 1998

System Pipeline

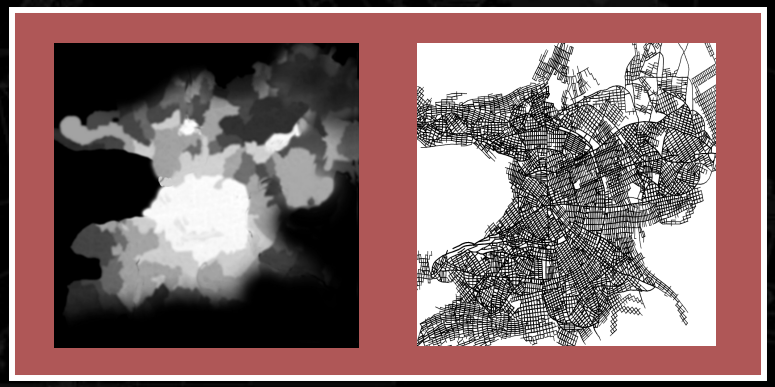


Module 1: Streetmap Creation

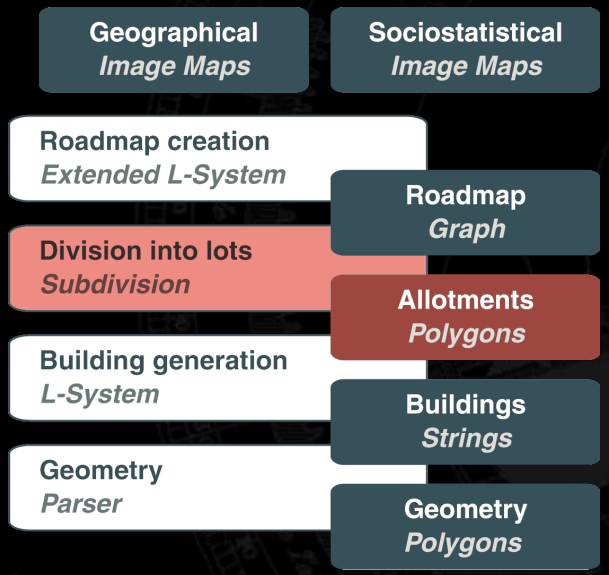


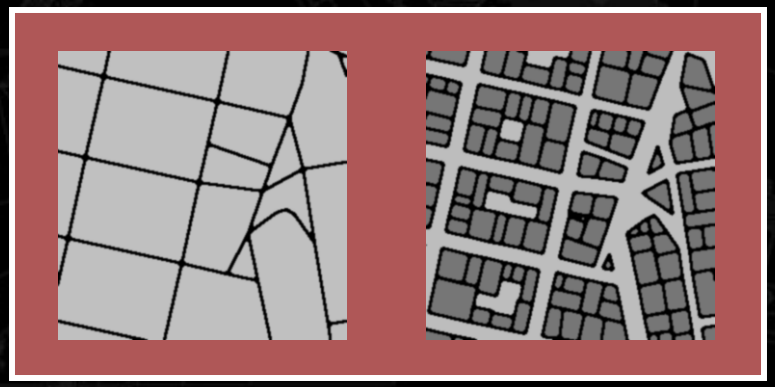
Input:
Image maps, parameters for rules

Output:
A street graph for interactive editing



Module 2: Division into Lots





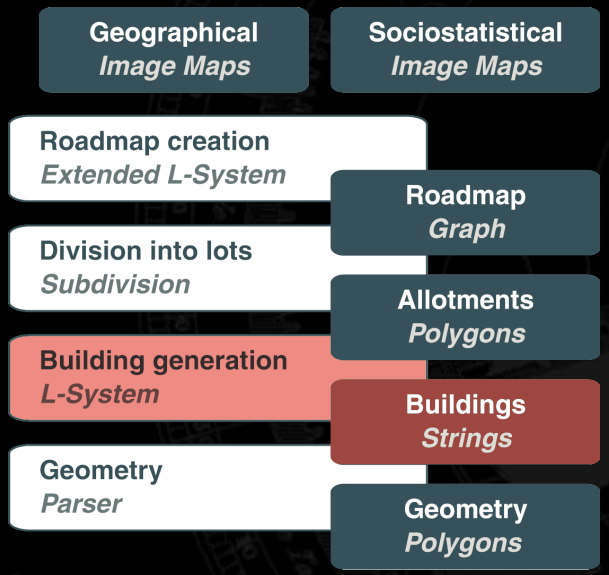
Input:

Street graph, area usage map

Output:

Polygon set of allotments for buildings

Module 3: Building Generation

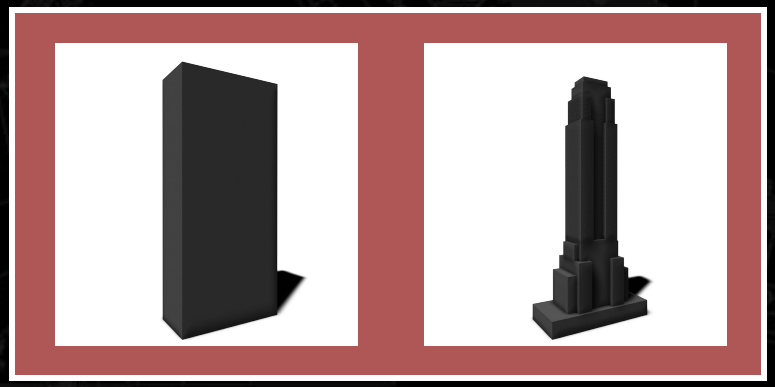


Input:

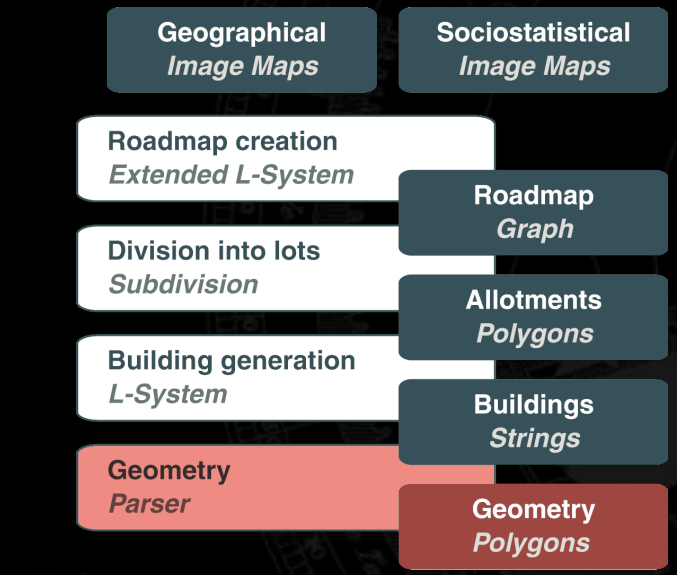
Lot polygons, age map and zone plan

Output:

Building strings with additional info



Module 4: Geometry and Facades

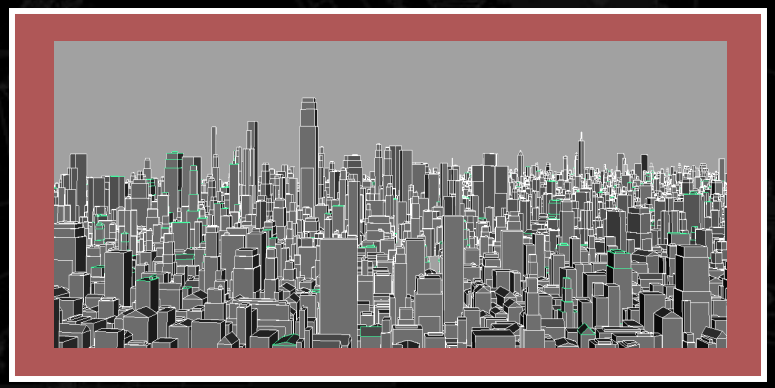


Input:

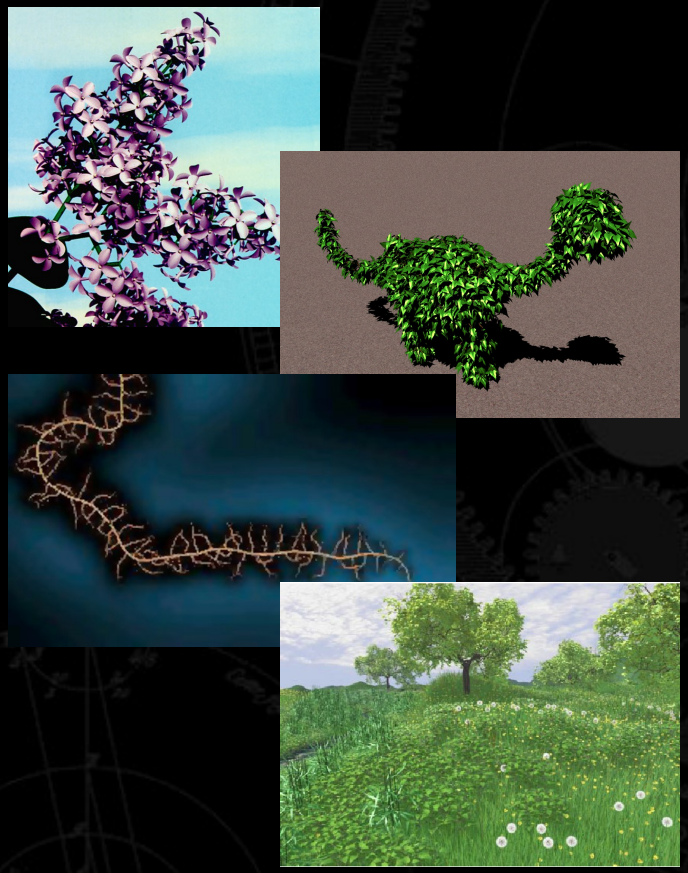
Strings and building type

Output:

City geometry and facade texture (procedural shader)



L-Systems



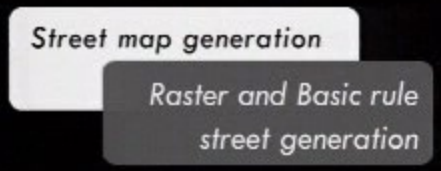
Generation of plants
Prusinkiewicz, Lindenmayer; 1990

Environment-sensitive
Prusinkiewicz, James, Mech; 1994

Interaction (Open L-System)
Mech, Prusinkiewicz; 1996

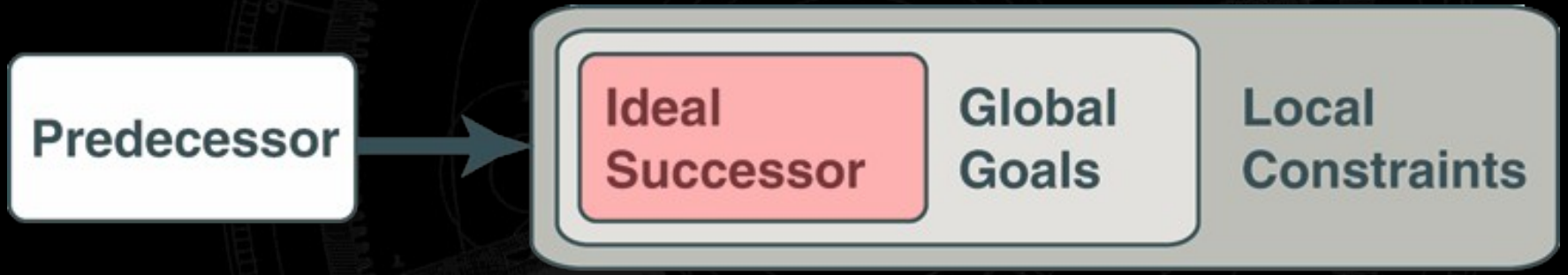
Ecosystems
Deussen, et al.; 1998

L-Systems for Streets



- Grouping parameters of different street patterns
- Hierarchical influences: global goals and local constraints

Extended L-Systems



- Template successor defines 3 branches
- Parameters fields are unassigned

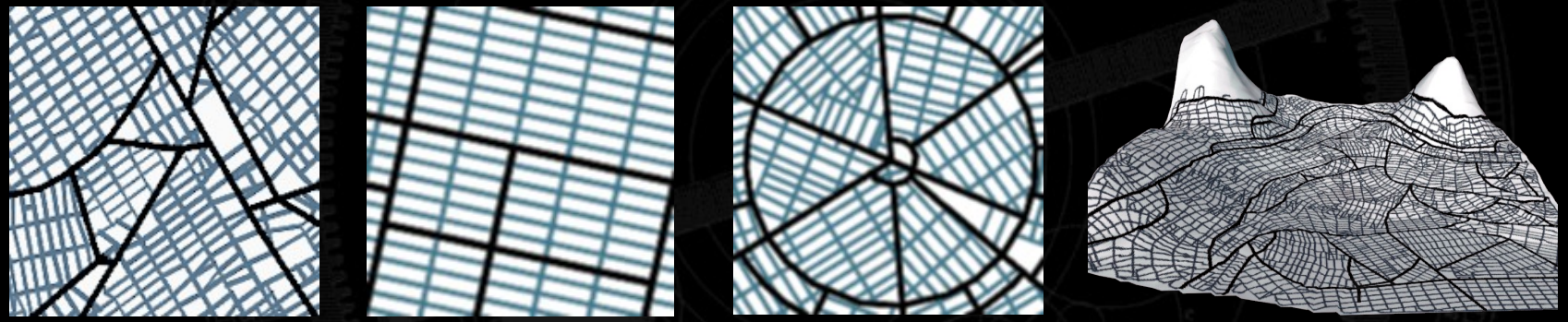
Extended L-Systems

- Initial parameter settings
- Design goal

Extended L-Systems

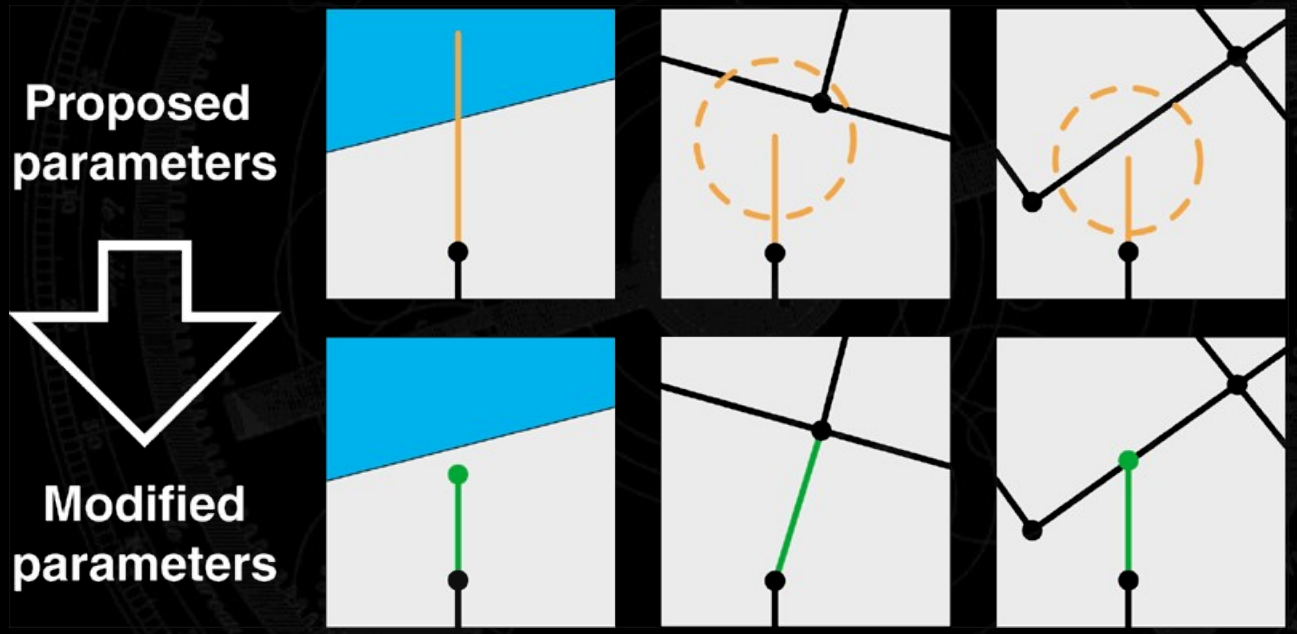
- Parameter value correction
- Influenced by local environment

Global Goals



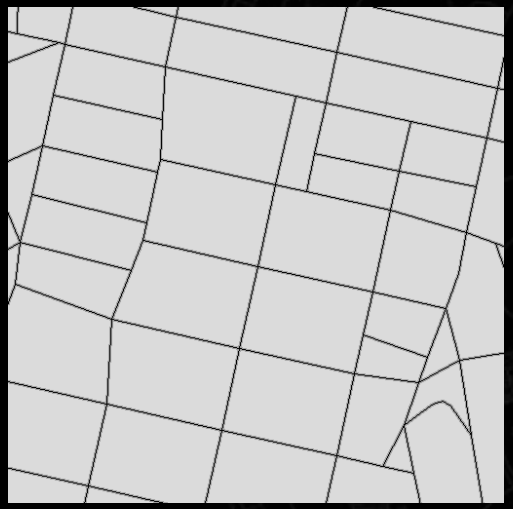
- Could be a planned urban design
- Different goals in the same city
- Controlled by image map (user input)

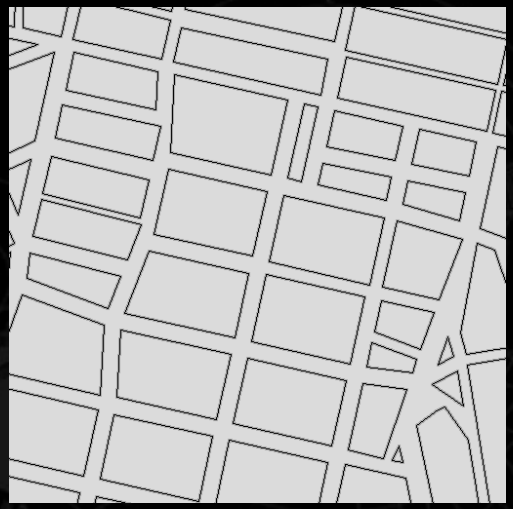
Local Constraints

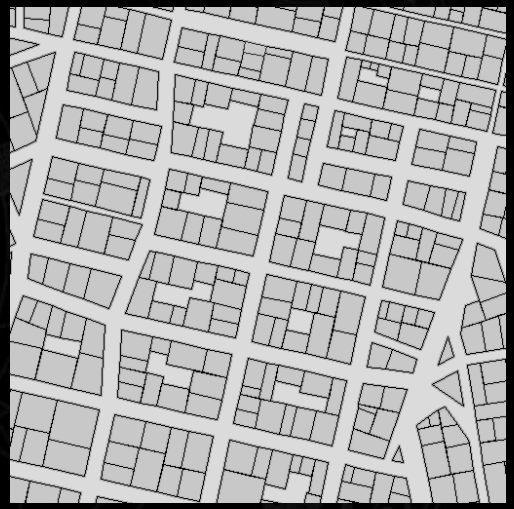


- Environment-sensitivity for legal streets
- Self-sensitivity for closed loops

Division into Lots



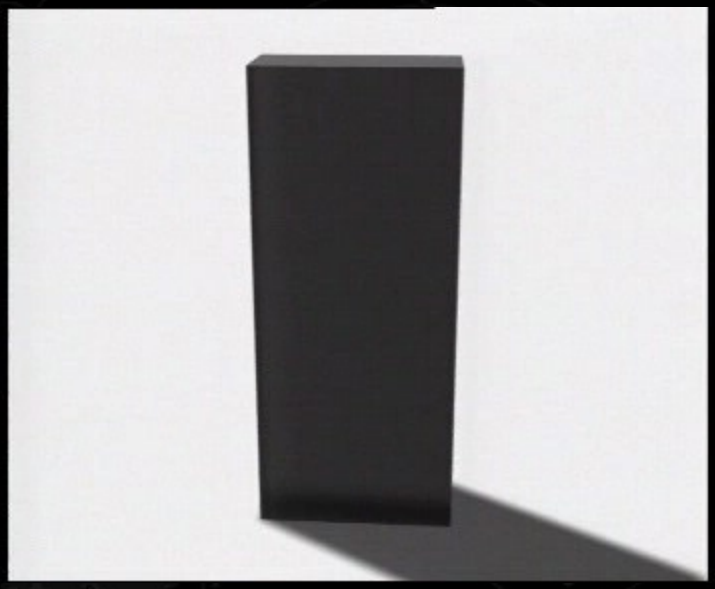




Lot area depends on:

- **Land Use map**
- **Population density**
- **Building height**
- **Access to street**

Procedural Buildings

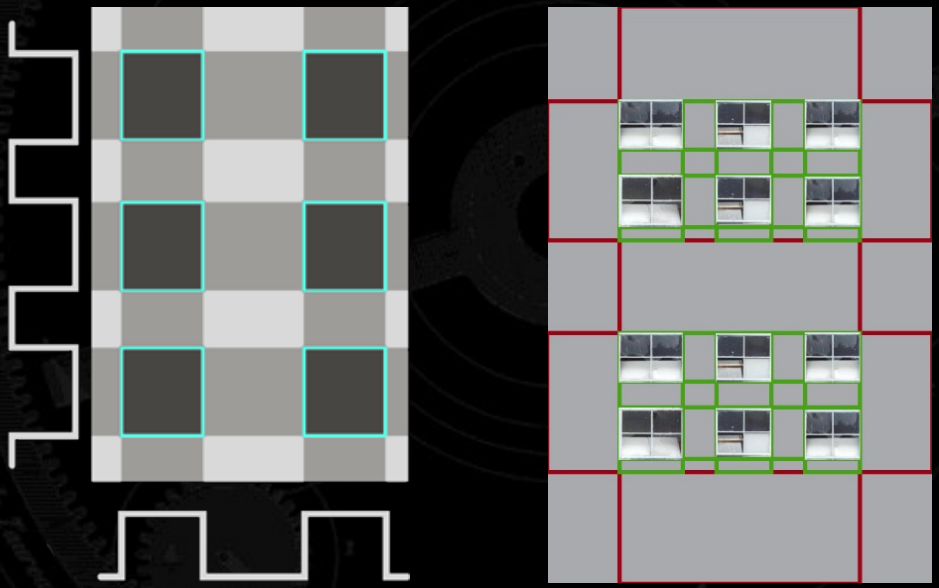


- Modeled with a common L-System
- L-System modules consist of geometric operations like extrusion

Facade Textures

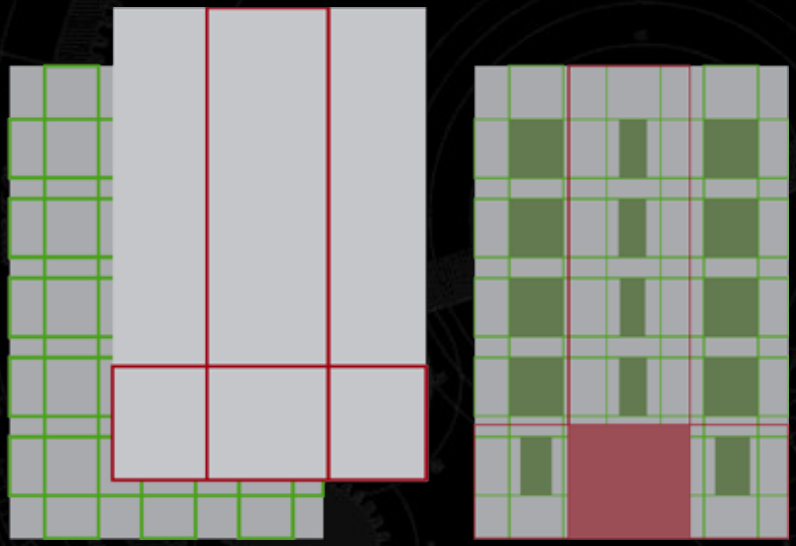
- Division into simple grid-like structures
- Structures can be layered

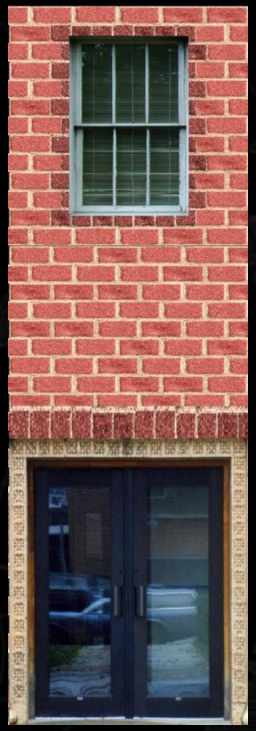
Layered Textures



- Two base functions form a layer
- Every layer defines a facade element

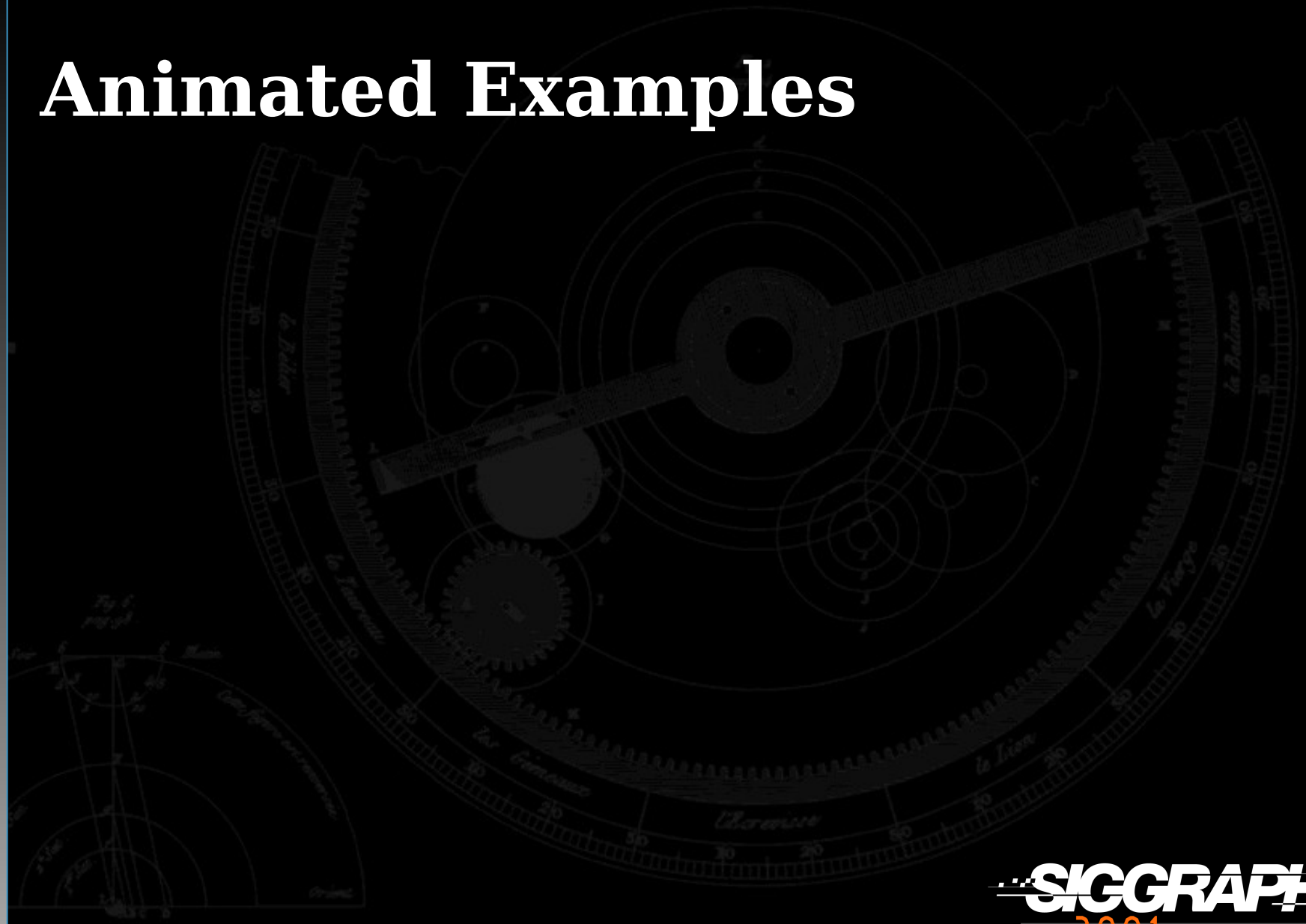
Layering of Planes





- Stacked layers for facade texture
- Functions between layers model relation between facade elements

Animated Examples



Future Work

- Temporal development of an urban area
- Function based grammar of buildings
- Bring life into the cities

Acknowledgments

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